Optical Imaging of the Nearshore

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Award #: N00014-09-10121
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LONG-TERM GOAL

The long-term goal of nearshore processes research has been to develop a predictive understanding of the fluid dynamics of a random wave field shoaling over the complicated bathymetry of a natural beach, and the response of the beach to those overlying wave and current motions (Holman, Bowen et al. 1990). Increasingly, it is recognized that limitations on our predictive capabilities are less tied to limitations in our understanding of the physics or modeling but instead result from our inability to easily obtain bathymetry and forcing data with which to feed the models. We seek remote sensing solutions to these problems.

OBJECTIVES

Our immediate objectives are to develop and test innovative methods to estimate nearshore bathymetry, wave forcing and hydrodynamic response using optical methods, to marry these capabilities with operational models and to understand the dynamics of the nearshore system that we measure.

APPROACH

The optical remote sensing methods developed over the years through the Argus Program lie at the heart of nearshore oceanographic research not just at the Coastal Imaging Lab, but also for an increasing global research community (Davidson, Van Koningsveld et al. 2007; Holman and Stanley 2007). Our research continues along two parallel themes: development of robust methods for making critical nearshore environmental measurements and understanding the dynamics revealed by those measurements.

We continue to test and improve the tools we have available to measure bathymetry/topography optically. A single frame image-based method has now been published that exploits the refractive turning of wave rays to estimate bathymetry gradients without need for information about wave period (Splinter and Holman 2009). We also continue to develop and exploit the use of stereo methods for sub-aerial topography measurement. These have been tested both at Duck, NC, and in a wave tank environment as part of a dune erosion experiment program (Figure 1) and yields O(4cm) accuracy (Clarke, van Thiel de Vries et al. in prep).

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2009**	2. REPORT TYPE	3. DATES COVERED **00-00-2009 to 00-00-2009**
4. TITLE AND SUBTITLE **Optical Imaging of the Nearshore**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Oregon State University,COAS-OSU,104 Ocean Admin Bldg,Corvallis,OR,97331-5503**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

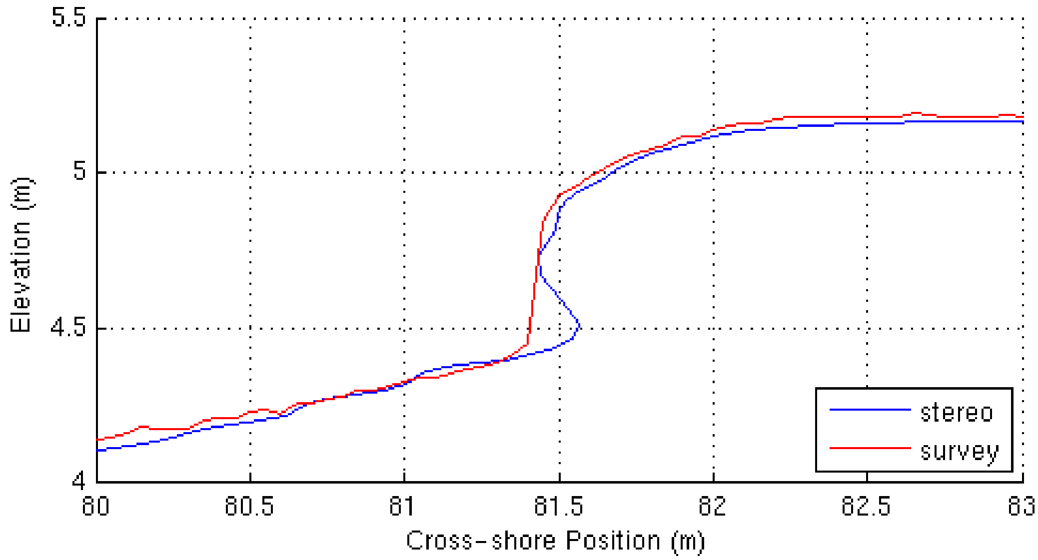

Figure 1. Comparison of stereo-derived (blue) and surveyed (red) topography for wave tank tests of a sand dune erosion. RMS differences were O(4cm). However because the in-situ senor was a vertical profiler, it was unable to capture the overhanging dune face.

In 2008, we became involved in a re-build of a celerity-based algorithm for estimating bathymetry called BeachWizard Lite (BWLite), jointly with Nathaniel Plant of the USGS and Todd Holland of NRL. This was originally a 1DH tomographic method (Plant, Holland et al. 2008) that applied robust signal processing to radiance time series from an array of pixels spread across the nearshore. This algorithm now works well in 2DH mode and the code has now been simplified from a research to an operational version. Tests are underway in Duck, NC, Eglin AFB and Agate Beach, Oregon. Analysis returns not just celerity-based bathymetry estimates, but also wavenumber-direction estimates for a user-specified number of frequencies that will be incorporated by colleagues into a more complete BeachWizard modeling package and into polarimetric data processing described below.

We have built and are testing a second polarimetric camera named Wolly to supplement Polly, the first such camera that has now been in operation at Duck for over one year (a third camera would be called Doodle). Issues of accurate gain control and co-registration have been dealt with so that AOLP and DOLP image data (Azimuth and Degree of Linear Polarization) are readily found. Polarimeters primarily measure the component of sea surface slope, transformed into the camera look direction, rather than sea surface elevation. Thus, polarimetric measurements are sensitive to high frequency noise. Thus, the transformation from the variance of AOLP measurements to wave height must be done spectrally and requires knowledge of wavenumber and angle that can be found from BWLite, as above.

We continue to study feedback in the nearshore system, a primary source of bathymetric variance. The dynamics of mesoscale sand bar variability (week to month time scales) and of the foreshore-swash system are both subject to strong feedbacks between the fluid motions and the bathymetric response and exhibit resulting variability. We continue to work with Brazilian colleagues (through a student,

Pedro Periera) on the dynamics of transient mud deposits that occasionally occur on southern beaches there.

Finally, we continue to work with Tuba Özkan-Haller and student Greg Wilson on the dynamics of 2DH circulation on complex topography.

WORK COMPLETED

A single frame method for estimating bathymetry gradients from refractive turning of waves (that requires no wave period information) has been published (Splinter and Holman 2009). A model for the dynamics of sand bar systems has been developed and tested based on >1100 days of data from the Argus Station at Palm Beach, Australia (Splinter 2009 and paper to be submitted). The model bridges the gap between physics-based sediment transport models and parametric (usually behavioral) models of sand bar variability, and directly addresses the relationship between cross-shore migration rates and the presence of alongshore bar variability (Figure 2).

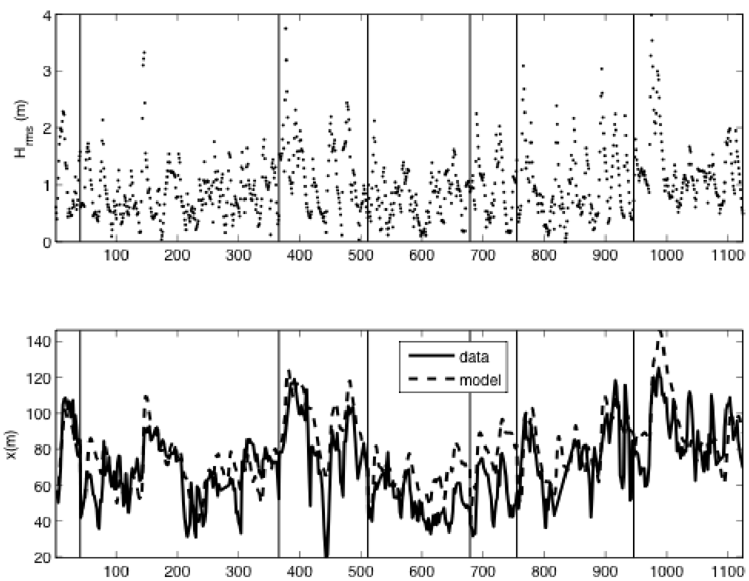

Figure 2. Time series of wave height and mean sand bar position variations over 1100 days of observation at Palm Beach Australia. Vertical lines mark breaks between the seven non-continuous data segments under study. The model, derived from a continuous sediment transport formulation but converted to a parametric form for bar position, specifically includes the role of 2DH circulation and explains 51% of the bar position variance.

We have completed a re-write of the research-level BWLite code into an operation package that we are testing in 2D mode against data in Duck and Agate Beach, OR. Finally, lead by Greg Wilson and joint with Tuba Özkan-Haller, we have proposed a simple explanation why alongshore variations of circulation are reduced under strong alongshore currents (Wilson, Özkan-Haller et al. in review; Wilson, Özkan-Haller et al. in review).

RESULTS

A new method has been published to estimate bathymetric gradients (hence bathymetry) based on single-frame snapshots of nearshore wave refraction with no requirement for wave period information (Splinter and Holman 2009). While applicable only for cases of narrow-banded seas with visible refractive turning, the simplified data requirements make this an interesting capability, especially in semi-enclosed sea environments.

A simplified model has been developed to explain the reduction in alongshore variability of circulation under strong longshore currents and a new parameter, the alongshore Reynolds number, has been proposed to parameterize this process (Wilson, Özkan-Haller et al. in review; Wilson, Özkan-Haller et al. in review).

IMPACT/APPLICATION

Nearshore remote sensing is of obvious importance to Naval Battlespace Characterization as well as to civilian applications in coastal zone management requiring extended observation (beyond the scope and available funding for focused experiments). The continual improvement in signal processing methods to reduce the high frequency noise that often dominates optics makes these methods robust, with well-understood statistics.

TRANSITIONS

The optical remote sensing approaches of Argus have been transitioned or are being further pursued in many ways. Argus has been made commercially available through transition agreements between OSU and Northwest Research Associates (for North America) and Delft Hydraulics (for the rest of the world) and is an accepted tool by the nearshore community throughout the world. Argus technology or spin-offs have been and are being actively used by the U.S Navy through products of the LRS program and, for NSW teams, through products of the research work of Dr. Todd Holland's group at NRL (we remain tightly connected to this group and are part of ongoing research on BWLite and UAV applications). The U.S. Army Corps of Engineers (through the FRF) continues to use Argus for both testing and applied projects. The USGS, particularly through Nathaniel Plant, also embraces Argus as an important tool in coastal monitoring and experimentation.

RELATED PROJECTS

1. Joint work with Dr. Todd Holland, NRL-SSC on BWLite and SUAV applications
2. Numerous collaborations with the USACE Field Research Facility including Morphos and XBeach testing and operations.
3. Work with USGS on BWLite (Plant) and shoreline vulnerability through foreshore-swash and dune erosion studies.

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Wilson, G. W., H. T. Özkan-Haller, et al. (in review). "Alongshore nonuniform dynamics in the surf zone: 2. application to field data." *Journal of Geophysical Research*.

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Wilson, G.W, Özkan-Haller, H.T. and R.A. Holman, Alongshore nonuniform dynamics in the surf zone: 2. Application to field data, J. Geophys. Res, in review. [refereed; in review]

PATENTS

None

HONORS/AWARDS/PRIZES

None